



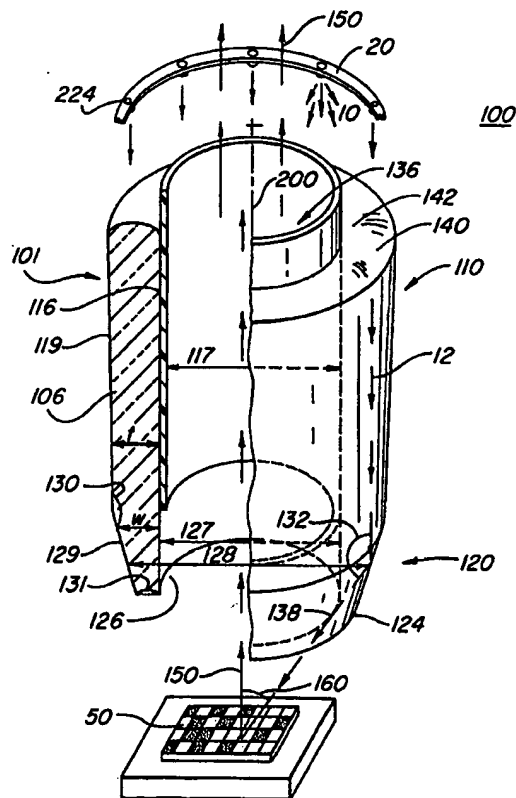
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : G02B 21/00, 21/06, 21/36	A1	(11) International Publication Number: WO 99/49347 (43) International Publication Date: 30 September 1999 (30.09.99)
(21) International Application Number: PCT/US99/05636 (22) International Filing Date: 17 March 1999 (17.03.99) (30) Priority Data: 09/045,623 20 March 1998 (20.03.98) US (71) Applicant: AUTO IMAGE ID, INC. [US/US]; Building 43, 2 Keystone Avenue, Cherry Hill, NJ 08003 (US). (72) Inventors: HAHN, James, C.; 276 Tarrington Court, Delran, NJ 08075 (US). BUBNOSKI, David, P.; 12 Columbia Drive, Marlton, NJ 08053 (US). SPATAFORE, Pat, L.; 1308 Woodhollow Drive, Marlton, NJ 08053 (US). (74) Agents: ROCCI, Steven, J. et al.; Woodcock Washburn Kurtz Mackiewicz & Norris LLP, 46th floor - One Liberty Place, Philadelphia, PA 19103 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published With international search report.

(54) Title: TARGET ILLUMINATION DEVICE

## (57) Abstract

A device for illuminating a target is provided. The target illumination device has a radiation source (20), a lens (140) and a deflector (120). The lens and the deflector are disposed in spaced apart relationship defining a transmission space (106) therebetween and a reflection space (136) proximate the transmission space. The lens is adapted to receive incident radiation from the radiation source and to transmit at least a portion of the incident radiation in a first direction through the transmission space in a manner such that the transmitted radiation is substantially uniform through the transmission space and such that the reflection space is substantially devoid of transmitted radiation. The deflector is adapted to be placed proximate a target (50) for deflecting at least a portion of the transmitted radiation onto the target at an angle such that the target reflects at least a portion of the deflected radiation in a second direction through the reflection space.



*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

## TARGET ILLUMINATION DEVICE

### FIELD OF THE INVENTION

The present invention relates to image readers. More particularly, the present invention relates to an target illumination device for use with an image reader.

5

### BACKGROUND OF THE INVENTION

To identify certain objects, such as electronic components, many industries, such as the automotive and electronics industries, often use indicia, such as bar codes or data matrix codes, etched onto the surface of the object. Typically, these indicia represent data used to identify the objects and, particularly in the case of electronic components, to accurately position the components during assembly. Generally, the indicia, or targets, are read by an image reader, such as a camera, positioned over the object. To provide the camera with a clear image of the indicia to be read, proper illumination of the indicia is essential.

Often, the surfaces onto which the indicia are etched are shiny, or mirror-like, surfaces. Proper illumination of many different shiny and uneven surfaces is critical, especially in a an application where robotic assembly is required. However, shiny, uneven surfaces are difficult to illuminate for accurate imaging. The uneven reflections from these surfaces frequently produce erroneous images and signals within the camera, thereby resulting in erroneous identification or positioning of the object.

Identification of objects is rapidly becoming a critical issue in the manufacture and sale of miniature components, particularly in the electronics industry. Identification is used to track faulty components during automated manufacturing processes. For example, it is costly to apply subsequent steps of the manufacturing process on a component that has been identified as faulty at an earlier step. By reading the identity of the component before each is step is applied, an automated manufacturing process can determine whether the component is faulty and, consequently, whether to apply the current step. Thus, if a component is

- 2 -

identified as faulty during one step of the manufacturing process, it can be ignored at all subsequent steps.

Similarly, object identification is also desirable in order to trace components once they have been shipped into the field. If a problem develops with a component in the field, the identification on the component provides a key to accessing historical information retained on the component at the factory. This historical information is invaluable in troubleshooting problems in the field.

One object identification technique that has been used with great success is the etching of bar codes onto the objects' surfaces. However, as components become smaller, it is necessary to fit more data into less surface area. In response, the etching of data matrix codes onto the objects' surfaces has begun to emerge as a preferred identification technique. Due to the large amount of data stored in such a small area, it is important that the image provided to the camera be as accurate as possible. Thus, to pick up the subtle contrasts in a data matrix code etched onto a highly reflective, uneven surface, proper target illumination has become even more critical.

Thus, there is a need in the art for a target illumination device that provides the necessary illumination of targets on highly reflective, uneven surfaces of miniature components such that an image reader can accurately process the image of the target.

### SUMMARY OF THE INVENTION

The present invention satisfies these needs in the art by providing a target illumination device comprising a radiation source, a lens, and a deflector. The present invention also provides a radiation directing device comprising a deflector and a lens, or a deflector and a wave guide. The radiation source comprises, for example, a plurality of light emitting diodes. The lens and the deflector are disposed in spaced apart relationship defining a transmission space therebetween and a reflection space proximate the transmission space. In a first embodiment, the reflection space and the transmission space are both symmetric around a central axis. In another embodiment, the reflection space is symmetric about a central plane, to which the transmission space is substantially parallel.

The lens is adapted to receive incident radiation from the radiation source and to transmit at least a portion of the incident radiation in a first direction through the transmission space in a manner such that the transmitted radiation is substantially uniform

- 3 -

through the transmission space and such that the reflection space is substantially devoid of transmitted radiation.

The deflector is adapted to be placed proximate a target and to deflect at least a portion of the transmitted radiation onto the target at an angle such that the target  
5 reflects at least a portion of the deflected radiation in a second direction through the reflection space. The deflector may have an inner wall and an outer wall, the outer wall forming an angle with the inner wall. The outer wall is adapted to deflect the transmitted radiation toward the target a predetermined angle.

In a preferred embodiment, the transmission space is contained within the  
10 inner and outer walls of a wave guide. The wave guide is adapted to receive the transmitted radiation and to guide the transmitted radiation to the deflector. The deflector has a first end adapted to receive at least a portion of the transmitted radiation and a second end adapted to prevent at least a portion of the transmitted radiation from passing therethrough. The lens and the deflector are integrally formed with the wave guide. Also,  
15 a trap may be disposed around a portion of the reflection space, on the inner walls of the wave guide and the deflector. The trap is adapted to prevent at least a portion of the transmitted radiation from entering the reflection space.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood, and its numerous objects  
20 and advantages will become apparent by reference to the following detailed description of the invention when taken in conjunction with the following drawings, in which:

FIG. 1 shows an embodiment of a target illumination device according to the present invention;

FIG. 2 shows a target illumination device according to the present invention  
25 in use in an image reader;

FIG. 3 shows a target illumination device according to the present invention in use with a hand-held image reader; and

FIG. 4 shows an embodiment of a target illumination device according to the present invention which is particularly suitable for reading linear indicia.

30 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

- 4 -

An apparatus which meets the above-mentioned objects and provides other beneficial features in accordance with the presently preferred exemplary embodiments of the invention will be described below with reference to Figures 1-4. Those skilled in the art will readily appreciate that the description given herein with respect to those figures is for explanatory purposes only and is not intended in any way to limit the scope of the invention. Accordingly, all questions regarding the scope of the invention should be resolved by referring to the appended claims.

FIG. 1 shows a preferred embodiment of a target illumination device according to the present invention. As shown in FIG. 1, a target illumination device 100 comprises a radiation source 20 and a device 101 for directing incident radiation 10 from radiation source 20 to a target 50. Preferably, incident radiation 10 is light. Radiation source 20, comprises a plurality of radiation emitters 224, preferably LEDs. By way of example, target 50 may be any of several indicia, such a bar code or a data matrix code, etched onto the surface of an object, such as an electronic component. Radiation directing device 101 comprises a lens 140 and a deflector 120. Lens 140 and deflector 120 are disposed in spaced apart relationship defining a transmission space 106 therebetween and a reflection space 136 proximate transmission space 106.

Lens 140 is adapted to receive incident radiation 10 and to transmit at least a portion of incident radiation 10 in a first direction through transmission space 106 to deflector 120 in a manner such that transmitted radiation 12 is substantially uniform through transmission space 106 and such that reflection space 136 is substantially devoid of transmitted radiation 12. Deflector 120 is adapted to be placed proximate target 50 and to deflect at least a portion of transmitted radiation 12 onto target 50 at an angle 160 such that target 50 reflects at least a portion of deflected radiation 138 in a second direction through reflection space 136.

In a preferred embodiment, radiation source 20 and lens 140 are constructed such that the irradiance (i.e., power per unit area) striking deflector 120 is nearly constant throughout any differential cross-section of transmission space 106. This is achieved by using a plurality of LEDs spaced as closely together as possible and an anamorphic lens.

The LEDs used have no optical components embodied within the LED structure itself. Thus, they individually serve as near point sources of highly divergent radiation. The divergence angle of the radiation from the LED source differs in the

- 5 -

meridional or tangential plane versus the sagittal plane. This divergence angle plays a role in determining the collection efficiency of the lens as described below.

In a preferred embodiment, lens 140 is a half-toroid. It serves as an anamorphic optical element. An anamorphic optical element is one in which the optical power or "light bending capability" is different in the sagittal plane versus the tangential plane. In the tangential plane, lens 140 collects and nearly collimates incident radiation 10 into transmission space 106. In the sagittal plane, which can be viewed as an infinitesimal arc segment of a circle which bisects the half-toroid, lens 140 has no power and incident radiation 10 continues to diverge in this plane. Some of this radiation remains in the transmission space overlapping radiation from the sagittal planes of contiguous LEDs and contributes to the irradiance uniformity in this direction in transmission space 106. (Note: it is contemplated that lens 140 may be designed such that a radius is constructed along the sagittal direction to control the divergence and overlap along this direction in transmission space 106. This would effectively break-up the half-toroid). The combinatorial effect of the lens is to efficiently collect the radiation and to provide a source of irradiance which is constant throughout any differential cross-section of transmission space 106.

As a second purpose in collecting and redirecting the radiation, lens 140 also prevents radiation from the highly divergent source from entering reflection space 136. This effect is augmented by the addition of trap 142, described more fully below. Interference, or noise, would be defined as radiation reflections from target 50 whose initial source was from a direction other than that coming from deflector 120. In keeping reflection space 136 devoid of any transmitted radiation 12, this interference is minimized, thus increasing the signal-to-noise performance of the device 101.

As shown in FIG. 1, the device of the present invention further comprises a wave guide 110. Wave guide 110 is adapted to receive transmitted radiation 12 and to guide transmitted radiation 12 to deflector 120. Wave guide 110 has an inner wall 116 and an outer wall 119. Transmitted radiation 12 is directed through wave guide 110 between inner wall 116 and outer wall 119. Thus, in the embodiment shown in FIG. 1, transmission space 106 is essentially contained between inner wall 116 and outer wall 119 of wave guide 110 and inner wall 116 of wave guide 110 forms a boundary of reflection space 136. By directing transmitted radiation 12 between inner wall 116 and outer wall

- 6 -

119, lens 140 prevents at least a portion of transmitted radiation 12 from entering reflection space 136.

Similarly, deflector 120 has an inner wall 126 and an outer wall 129. Inner wall 126 of deflector 120 also forms a boundary of reflection space 136. Outer wall 129 of deflector 120 forms an angle 131 with inner wall 126 of deflector 120 and an angle 130 with outer wall of wave guide 110. Deflector 120 may be fixedly connected with wave guide 110, or deflector 120 may be integrally formed with wave guide 110. Outer wall of deflector 120 is adapted to deflect transmitted radiation 12 at an angle 132 toward target 50.

10 In a preferred embodiment shown in FIG. 1, reflection space 136 is symmetric around a central axis 200. Similarly, transmission space 106 is symmetric around central axis 200. The axial symmetry of deflected radiation 138 on target 50 provides several advantages. Because the incidence angle from the target surface normal to the radiation is controlled, the specularly reflected component of the radiation is known and directed away from the imaging device in all directions. Thus, the reflection from specular or highly reflective surfaces on which codes have been marked will not reach the imaging device. If the specular reflection did reach the imaging device, it could produce a signal exceeding the dynamic range of the imaging device. This would prevent the imaging device from producing the desired result of successfully detecting the marked code, whose diffuse component of reflection is usually at a much lower radiant intensity (watts per solid angle).

20 The axial symmetry of the radiation incident on the target also increases the consistency and uniformity of the diffuse reflected component of radiation from uneven surfaces. Uneven surfaces when illuminated from one particular direction at a predetermined angle will cause shadows and other reflection irregularities. Sometimes this may be desired to enhance the contrast of a surface irregularity as in the case of flaw detection.

25 In the case of code reading, the marked surface as well as the background surface may be irregular and/or uneven. The reflection irregularities caused by the combination of the surface irregularities and the construction of the target illumination will cause a noise component to be induced on the nominal contrast value of the background



- 7 -

and/or the marked portion of the code. This can reduce the overall performance of the imaging/reading system.

By using directional illumination which is symmetric about the surface normal to the target, the reflection irregularities caused by surface irregularities (unevenness) are minimized. Shadows caused by one direction of illumination are filled in by the other directions uniformly. This serves to reduce the contrast noise described above while at the same time eliminating specular reflection in the image, increasing the overall signal-to-noise performance of the system.

As shown in FIG. 1, wave guide 110 is essentially a hollow cylinder and deflector 120 is essentially a hollow frustum, each of which has an annular cross-section. Preferably, the inner diameter 127 of deflector 120 is equal to the inner diameter 117 of wave guide 110. Inner wall 116 of wave guide 110 and inner wall 126 of deflector 120 are each disposed symmetrically around central axis 200. Thus, inner wall 116 of wave guide 110 and inner wall 126 of deflector 120 form a boundary of reflection space 136. Deflector 120 has a varying outer diameter 128 and, consequently, a varying thickness, w. Preferably, at end 124 of deflector 120 thickness, w, is nearly zero. Similarly, lens 140 is disposed symmetrically around central axis 200. Preferably, lens 140 is essentially a ring or half-toroid having an annular cross-section and radiation source 20, is a ring of radiation emitters, such as LEDs. It is contemplated that wave guide 110 and deflector 120 may each be hollow frustums symmetric around central axis 200 (i.e., radiation directing device 101 would be essentially conical in shape). In this embodiment, lens 140 may be a ring as described above, as would radiation source 20. Again, wave guide 110, deflector 120, and lens 140 each would have an annular cross-section.

In the embodiment shown in FIG. 1, the directions of travel for transmitted radiation 12 and reflected radiation 150 are substantially opposite one another. Similarly, the directions are substantially parallel. However, this is primarily a result of the cylindrical overall shape of radiation directing device 101. The benefit is to minimize the overall size of device 101 in directions radially perpendicular to central axis 200. In an embodiment wherein radiation directing device 101 is, for example, conical (as described above), the directions of travel for transmitted radiation 12 and reflected radiation 150 would not be parallel.

As shown in FIG. 1, deflector 120 and lens 140 are integrally formed with wave guide 110. Outer diameter 128 of deflector 120 varies such that outer wall 129 of deflector 120 forms angle 130 with outer wall 119 of wave guide 110. Thus, in the embodiment shown in FIG. 1, deflector 120 is essentially a tapered, or beveled, end of radiation directing device 101. Thus, it is an advantage of the present invention that the embodiment shown in FIG. 1 can be formed from a tube having a suitable outer diameter 118, inner diameter 117, and thickness,  $t$ . Preferably, the tube is made of clear acrylic and is lathed on one end to form deflector 120, and ground on the other end to form lens 140. The length of inner wall 126 of deflector 120 is optimized for each application (i.e., set to ensure that transmitted radiation 12 is deflected uniformly toward target 50).

The optical characteristics of the transmission medium should be suited to the characteristics of the radiation. In the case of an acrylic tube, the material provides a near lossless transmission medium for the wavelength of the radiation used (for example, 660 nm nominally).

In the embodiment shown in FIG. 1, the radius of the lens is related to the waveguide thickness. The radius of the lens, which determines its focal length and therefore optical power, dictates the placement of the radiation source relative to the device so as to provide the desired collection and redirection of the incident radiation.

The collection efficiency of the lens is related to the divergence angle of the radiation previously mentioned. For maximum efficiency, the F number of the lens, which is related to the ratio of the lens' focal length to its diameter, should be low enough to collect as much of the radiation as possible while providing the desired redirection characteristics. Since the lens radius, which determines focal length, is related to waveguide thickness in this embodiment, the desired waveguide thickness is driven by this relationship.

The length of the waveguide is arbitrary. It may depend, however, on the optical characteristics of the imaging lens. The illumination device should be of suitable length such that it illuminates the target at the proper angle and distance where the target is in focus on the imaging device.

A trap 142 is disposed around at least a portion of reflection space 106. Trap 142 is adapted to prevent at least a portion of transmitted radiation 12 from entering reflection space 106. For example, trap 142 may be opaque or reflective. Preferably, trap

- 9 -

142 is disposed around the entire inner wall 116 of wave guide 110 and extends beyond the top of radiation directing device 101 as shown in FIG. 1.

It has been observed that, especially when a clear, acrylic tube is used to form radiation directing device 101, a portion of incident radiation 10 is not deflected, but passes through outer wall 129 of deflector 120. Thus, to decrease the amount of incident radiation 10 that passes through outer wall 129, and to increase the efficiency of radiation directing device 101, an opaque or reflective surface may be disposed around outer wall 129 of deflector 120. Similarly, in an embodiment in which deflector end 124 has a nonzero width, it has been observed that a portion of transmitted radiation 12 passes through deflector end 124. Deflector end 124 acts as a lens, focusing any transmitted radiation 12 that passes therethrough onto points on target 50, rather than uniformly distributing the radiation. These points are commonly known as "hot-spots" and cause interference with the image of the target as seen by an image reader, for example. Thus, end 124 of deflector 120 is adapted to prevent at least a portion of transmitted radiation 12 from passing therethrough. For example, to decrease the amount of transmitted radiation 12 that passes through deflector end 124, deflector end 124 may be made opaque or reflective.

FIG. 2 shows a target illumination device 100 according to the present invention in use in an image reader, an application for which the invention is particularly suited. In the application shown, a plurality of objects 210, such as electronic components, are located on a moving surface 202, such as a conveyor belt. A target 50, such as a data matrix code, is disposed, such as by etching, on each object 210. An image reader 220, such as a data matrix code reader, is situated over moving surface 202. Image reader 220 comprises a camera lens 226 and an image sensor 228. Image sensor 228 may be, for example, a charge coupled device (CCD). A target illumination device 100 is coupled to image reader 220. Radiation source 20, shown as a ring of LEDs 224, is disposed between image reader 220 and radiation directing device 101. As shown in FIG. 2, radiation directing device 101 is positioned such that central axis 200 is substantially vertical, with deflector end 124 nearest to moving surface 202. In operation, as moving surface 202 moves objects 210 past image reader 220, radiation source 20 emits incident radiation 10. Lens 140 receives incident radiation 10 and transmits at least a portion of incident radiation 10 through wave guide 110. Deflector 120 deflects at least a portion of

- 10 -

transmitted radiation 12 toward target 50. Deflected radiation 138 is reflected off of target 50 through reflection space 136. Reflected radiation 150 is redirected by camera lens 226 to image sensor 228. Image reader 220 interprets information contained in reflected radiation 150 by processes known in the art.

5           FIG. 3 shows a target illumination device according to the present invention in use with a hand-held image reader. In the application shown, a target 50, such as a data matrix code, is disposed, such as by etching, on an object 210. Hand-held image reader 420 comprises a camera lens 226 and an image sensor 228. Hand-held image reader 420 may be, for example, a data matrix code reader. Image sensor 228 may be, for example, a charge coupled device (CCD). As shown, a target illumination device 100 is  
10           coupled to image reader 420. Radiation source 20, shown as a ring of LEDs 224, is disposed between image reader 420 and radiation directing device 101. Radiation directing device 101 is positioned such that central axis 200 is substantially perpendicular to image reader 420, with deflector end 124 farthest from image reader 420. In operation,  
15           a user places image reader 420 over target 50 in a manner such that target 50 is surrounded, at least in part, by deflector 120. Deflector end 124 is particularly suited to aid the user in positioning the target within the viewing area. The user simply adjusts the attitude of hand-held image reader 420 until deflector end 124 is flush against the surface on which target 50 is located and moves hand-held image reader 420 until target 50 is  
20           located beneath reflection space 136. In so doing, radiation directing device is substantially vertical, insuring that deflected radiation 138 will uniformly and symmetrically illuminate target 50.

          To read the information represented by indicia 50, radiation source 20 emits incident radiation 10. Lens 140 receives incident radiation 10 and transmits at least a  
25           portion of incident radiation 10 through wave guide 110. Deflector 120 deflects at least a portion of transmitted radiation 12 toward target 50. Deflected radiation 138 is reflected off of target 50 through reflection space 136. Reflected radiation 150 is redirected by camera lens 226 to image sensor 228. Image reader 420 interprets information contained in reflected radiation 150 by processes known in the art.

30           FIG. 4 shows an embodiment of a target illumination device according to the present invention which is particularly suitable for reading linear indicia, such as bar codes. As shown in FIG. 4, target illumination device 102 comprises a radiation source 20

- 11 -

and a pair of plates 300. Radiation source 20, comprises a plurality of radiation emitters 224, preferably LEDs. Plates 300 are substantially parallel to each other and separated by a distance,  $d$ . Plates 300 may be coupled to one another and kept parallel to one another by the use of spacers, for example.

5           Each plate 300 comprises a deflector 320, a wave guide 310, and a lens 340. Each deflector 320 has an inner wall 326. Inner walls 326 of deflectors 320 form boundaries of a reflection space 336. Reflection space 336 is symmetric about a central plane 360. Inner walls 326 of deflectors 320 are substantially parallel to central plane 360. Similarly, each wave guide 310 has an inner wall 316. Inner walls 316 of wave guides 310  
10   are also substantially parallel to central plane 360. Preferably, inner wall 316 of wave guide 310 is coplanar with inner wall 326 of deflector 320. Lenses 340 are disposed substantially parallel to central plane 360. Each lens 340 is adapted to receive incident radiation 10 from radiation source 20 and to transmit at least a portion of incident radiation 10 to deflector 320 in a manner such that transmitted radiation 12 is substantially uniform  
15   and such that reflection space 336 is substantially devoid of transmitted radiation. Wave guide 310 is adapted to receive transmitted radiation 12 and to guide transmitted radiation 12 through wave guide 310 to deflector 320. Each deflector 320 is adapted to be placed proximate target 50 to deflect at least a portion of transmitted radiation 12 toward target 50 in a manner such that at least a portion of deflected radiation 138 is reflected off of target  
20   50 into reflection space 336.

          In the embodiment shown in FIG. 4, wave guide 310 has an outer wall 319. Transmitted radiation 12 is directed through wave guide 310 between inner wall 316 and outer wall 319. Thus, a transmission space 306 is contained between outer wall 319 and inner wall 316 of wave guide 310. Similarly, deflector 320 has an outer wall 329. Outer  
25   wall 329 of deflector 320 forms an angle 330 with outer wall 319 of wave guide 310. Wave guide 310 has a thickness,  $t$ , and deflector 320 has a varying thickness,  $w$ . Preferably, end 324 of deflector 320 has a nonzero thickness. Thus, deflector 320 is essentially a tapered, or beveled, end of plate 300. The length of inner wall 326 of deflector 320 is optimized for each application (i.e., set to ensure that transmitted radiation  
30   12 is deflected uniformly toward target 50.

          In a preferred embodiment, a trap 342 is disposed on at least a portion of inner wall 316 of wave guide 310. Trap 342 is adapted to prevent at least a portion of

- 12 -

transmitted radiation 12 from entering reflection space 336. Thus, it is preferred that trap 342 be disposed on the entire inner wall 316 of wave guide 310. Trap 342 may be an opaque or reflective surface, for example.

As shown in FIG. 4, deflector 320 and lens 340 are integrally formed with  
5 wave guide 310. Thus, it is an advantage of the present invention that plate 300 can be formed from a sheet having a thickness suitable for wave guide 310. The sheet, which, preferably, is made of clear acrylic, is lathed on one end to form deflector 320, and ground on the other end to form lens 340.

It has been observed that, especially when a clear, acrylic sheet is used to  
10 form plate 300, a portion of transmitted radiation 12 is not deflected off of deflector 320, but passes through outer wall 329 of deflector 320. Thus, a reflective surface, such as a mirror, may be disposed on outer wall 329 of deflector 320 to prevent at least a portion of transmitted radiation 12 from passing through outer wall 329. Similarly, it has been observed that, if deflector end 324 has a nonzero width, a portion of deflected radiation  
15 138 passes through deflector end 324. Thus, deflector end 324 may be made opaque or reflective to decrease the amount of deflected radiation 138 that passes through deflector end 324.

While the invention has been described and illustrated with reference to specific embodiments, those skilled in the art will recognize that modification and  
20 variations may be made without departing from the principles of the invention as described hereinabove and set forth in the following claims.

## WE CLAIM:

1. A device for directing incident radiation from a radiation source to a target, said device comprising:
  - a lens and a deflector disposed in spaced apart relationship defining a transmission space therebetween and a reflection space proximate said transmission space, said lens being adapted to receive said incident radiation and to transmit at least a portion of said incident radiation in a first direction through said transmission space in a manner such that said transmitted radiation is substantially uniform through said transmission space and such that said reflection space is substantially devoid of said transmitted radiation,
  - said deflector adapted to be placed proximate said target and to deflect at least a portion of said transmitted radiation onto said target at an angle such that said target reflects at least a portion of said deflected radiation in a second direction through said reflection space.
2. The device of claim 1, wherein said reflection space is symmetric around a central axis, and wherein said transmission space is symmetric around said central axis.
3. The device of claim 1, wherein said reflection space is symmetric about a central plane, and wherein said transmission space is substantially parallel to said central plane.
4. A device for directing incident radiation from a radiation source to a target, said device comprising:
  - a deflector having an inner wall, the inner wall of said deflector forming a boundary of a reflection space, said deflector adapted to be placed proximate said target,
  - said deflector adapted to deflect at least a portion of said transmitted radiation toward said target in a manner such that at least a portion of said deflected radiation is reflected off of said target through said reflection space; and

- 14 -

a lens adapted to receive said incident radiation and to transmit at least a portion of said incident radiation to said deflector in a manner such that said transmitted radiation is substantially uniform and such that said reflection space is substantially devoid of said transmitted radiation.

- 5           5.     The device of claim 4, further comprising:  
a trap disposed around a portion of said reflection space, said trap adapted to prevent at least a portion of said transmitted radiation from entering said reflection space.
- 10           6.     The device of claim 4, wherein said deflector has an outer wall, the outer wall of said deflector forming a first angle with the inner wall thereof, the outer wall of said deflector adapted to deflect said transmitted radiation toward said target at a second angle.
- 15           7.     The device of claim 4, wherein said deflector has a first end and a second end, the first end of said deflector adapted to receive at least a portion of said transmitted radiation, the second end of said deflector adapted to prevent at least a portion of said transmitted radiation from passing therethrough.
8.     The device of claim 4, further comprising:  
a wave guide, said wave guide adapted to receive said transmitted radiation and to guide said transmitted radiation to said deflector.
- 20           9.     The device of claim 8, wherein said lens is integrally formed with said wave guide.
10.    The device of claim 8, wherein said deflector is integrally formed with said wave guide.
- 25           11.    A device for directing incident radiation from a radiation source to a target, said device comprising:



- 15 -

a deflector having an inner wall, the inner wall of said deflector forming a boundary of a reflection space, said reflection space having a central axis, the inner wall of said deflector disposed symmetrically around said central axis, said deflector adapted to be placed proximate said target, said deflector adapted to receive transmitted radiation and to  
5 deflect at least a portion of said transmitted radiation toward said target in a manner such that at least a portion of said deflected radiation is reflected off of said target through said reflection space; and

a lens disposed symmetrically around said central axis, said lens adapted to receive said incident radiation and to transmit at least a portion of said incident radiation to  
10 said deflector in a manner such that said transmitted radiation is substantially uniform.

12. The device of claim 11, wherein said lens is further adapted to transmit at least a portion of said incident radiation to said deflector in a manner such that said reflection space is substantially devoid of said transmitted radiation.

13. The device of claim 11, further comprising:  
15 a wave guide having an inner wall, the inner wall of said wave guide disposed symmetrically around said central axis, said wave guide adapted to receive said transmitted radiation and to guide said transmitted radiation to said deflector.

14. The device of claim 13, wherein said deflector has an essentially annular cross-section, wherein said wave guide has an essentially annular cross-section,  
20 and wherein said lens has an essentially annular cross-section.

15. The device of claim 13, wherein said deflector is integrally formed with said wave guide, and wherein said lens is integrally formed with said wave guide.

16. A device for directing incident radiation from a radiation source to a target, said device comprising:  
25 at least two deflectors, each said deflector having an inner wall, the inner wall of each said deflector forming a boundary of a reflection space, said reflection space having a central plane, the inner wall of each said deflector substantially parallel to said

- 16 -

central plane, each said deflector adapted to be placed proximate said target, each said deflector adapted to deflect at least a portion of said transmitted radiation toward said target in a manner such that at least a portion of said deflected radiation is reflected off of said target through said reflection space; and

5 a lens disposed substantially parallel to said central plane, said lens adapted to receive said incident radiation and to transmit at least a portion of said incident radiation to said deflectors in a manner such that said transmitted radiation is substantially uniform.

17. The device of claim 16, wherein said lens is further adapted to transmit at least a portion of said incident radiation to said deflectors in a manner such that  
10 said reflection space is substantially devoid of said transmitted radiation.

18. The device of claim 16, further comprising:

a wave guide having an inner wall, the inner wall of said wave guide substantially parallel to said central plane, said wave guide adapted to receive said transmitted radiation and to guide said transmitted radiation to at least one said deflector.

15 19. A device for directing transmitted radiation to a target, said device comprising:

a wave guide and a deflector disposed in spaced apart relationship, said wave guide containing a transmission space, a reflection space defined proximate said transmission space,

20 said wave guide adapted to receive said transmitted radiation and to guide at least a portion of said transmitted radiation to said deflector in a first direction through said transmission space,

said deflector adapted to be placed proximate said target and to deflect at least a portion of said transmitted radiation onto said target at an angle such that said target  
25 reflects at least a portion of said deflected radiation in a second direction through said reflection space.

- 17 -

20. The device of claim 19, wherein said reflection space is symmetric around a central axis, and wherein said wave guide has an inner wall, the inner wall of said wave guide disposed symmetrically around a central axis of said reflection space.

21. The device of claim 19, wherein said reflection space is symmetric  
5 about a central plane, and wherein said wave guide has an inner wall, the inner wall of said wave guide substantially parallel to said central plane.

22. The device of claim 19, wherein said deflector is integrally formed with said wave guide.

23. A device for illuminating a target, said device comprising:  
10 a radiation source, a lens, and a deflector,  
said lens and said deflector disposed in spaced apart relationship defining a transmission space therebetween and a reflection space proximate said transmission space,  
said lens being adapted to receive incident radiation from said radiation source and to transmit at least a portion of said incident radiation in a first direction  
15 through said transmission space in a manner such that said transmitted radiation is substantially uniform through said transmission space and such that said reflection space is substantially devoid of said transmitted radiation,  
said deflector adapted to be placed proximate a target and to deflect at least a portion of said transmitted radiation onto said target at an angle such that said target  
20 reflects at least a portion of said deflected radiation in a second direction through said reflection space.

24. The device of claim 23, wherein said radiation source comprises a plurality of light emitting diodes.

**FIG. 1**

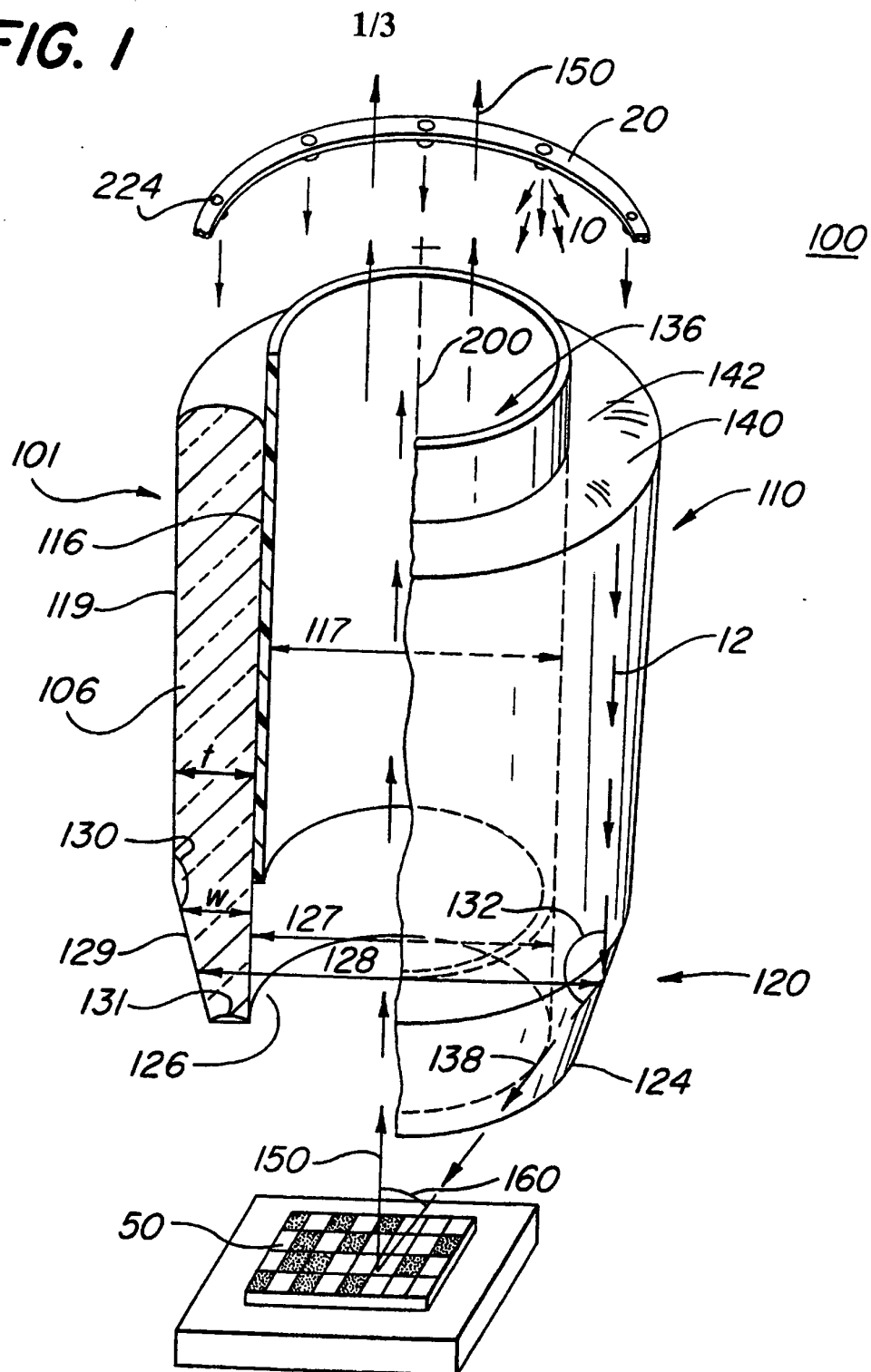
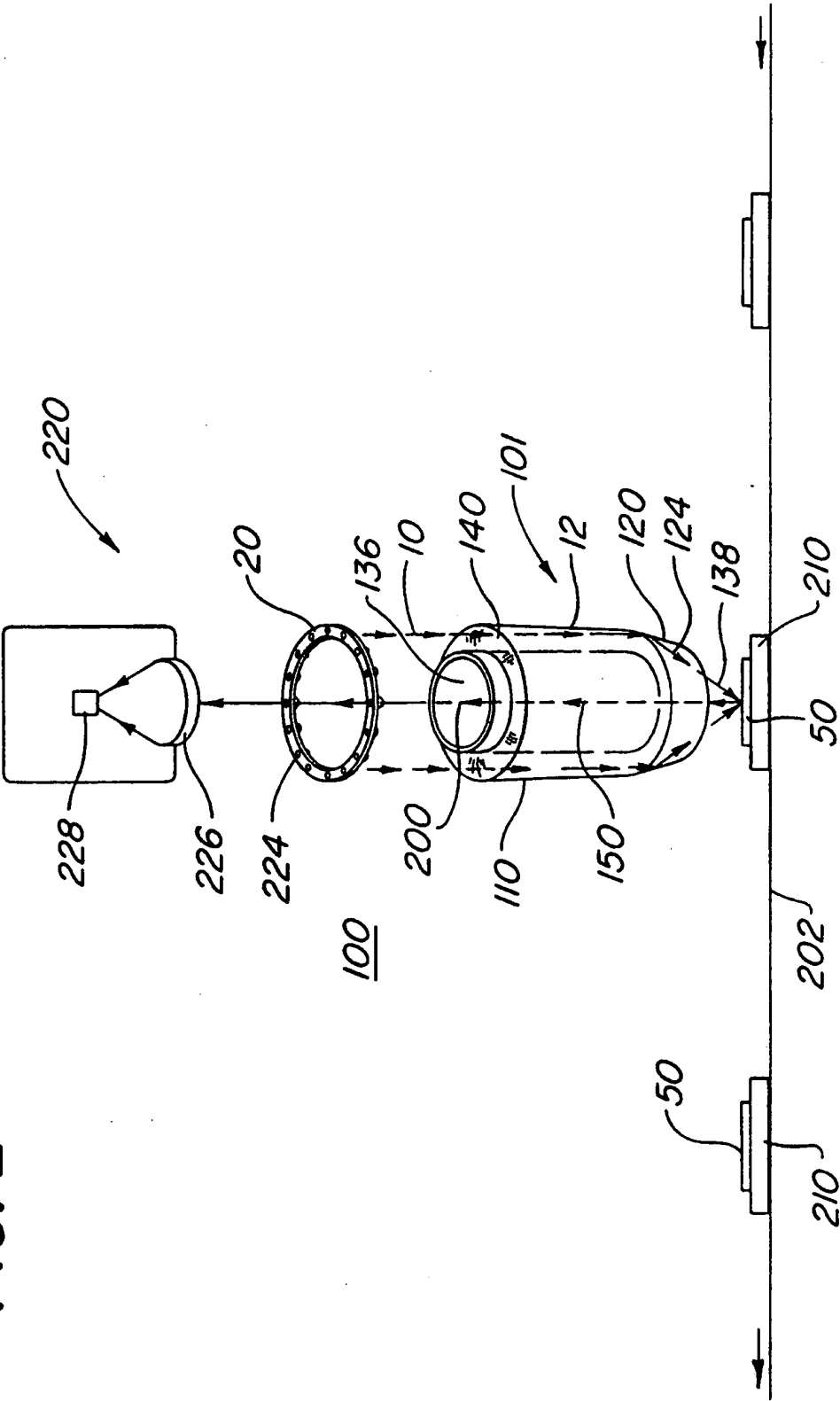
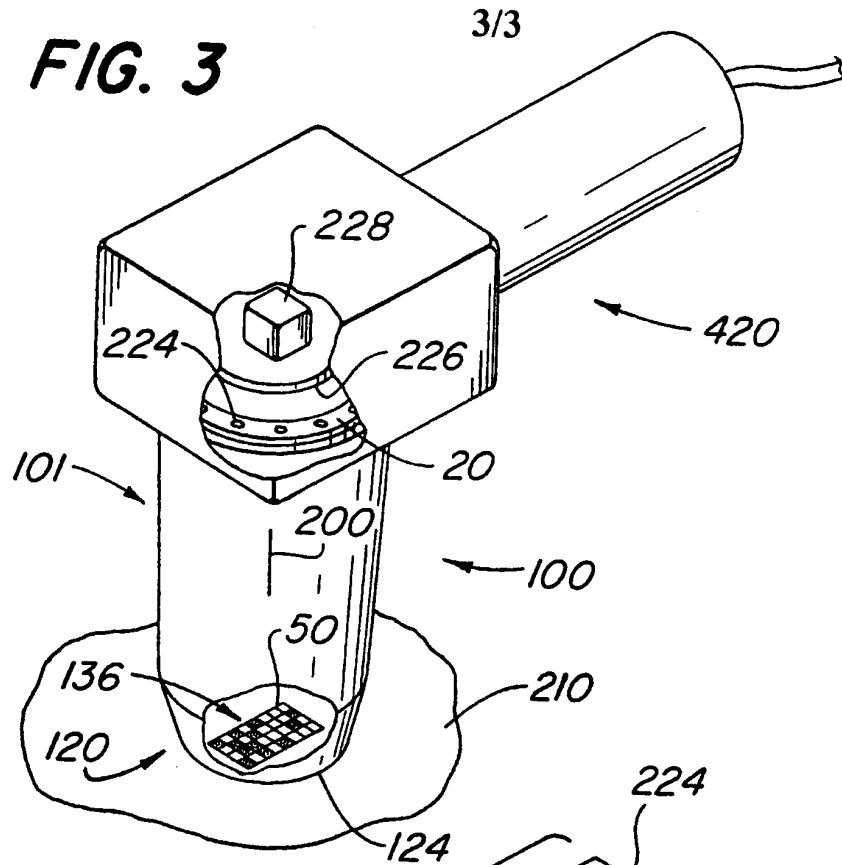
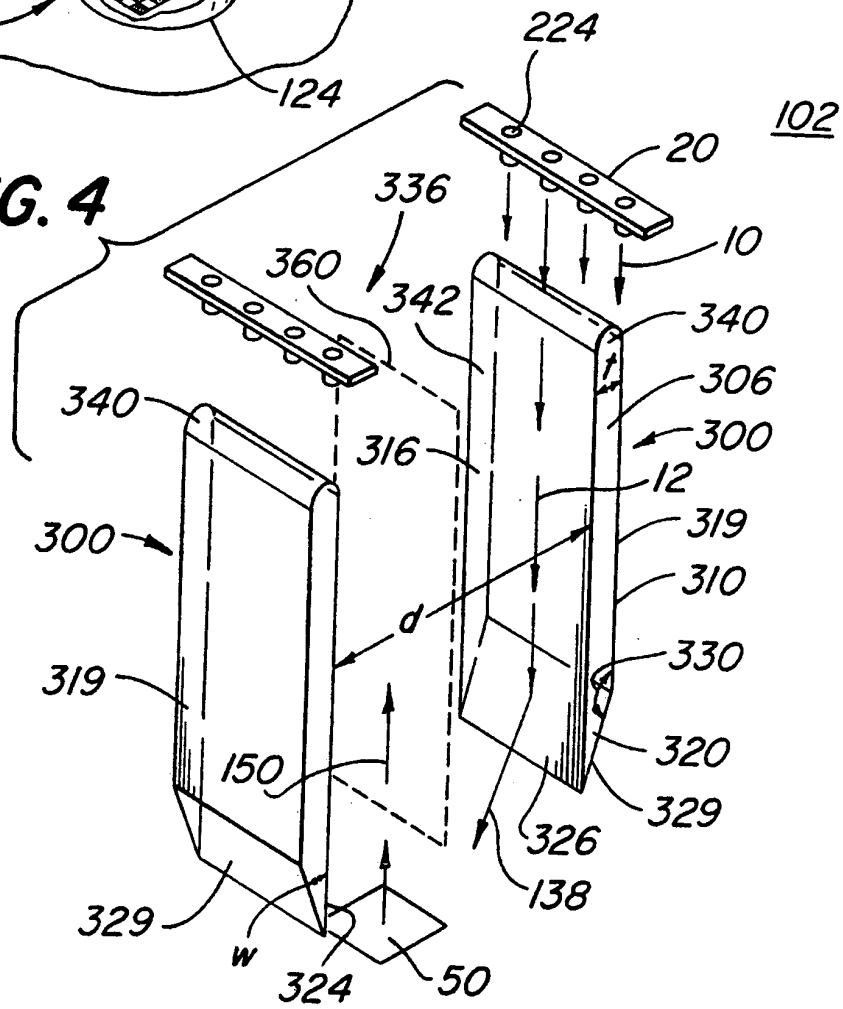


FIG. 2



**FIG. 3****FIG. 4**

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US99/05636

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(6) : G02B 21/00, 21/06, 21/36 US CL : 359/362-363, 368, 385-390 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) U.S. : 359/362-363, 368, 385-390 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) NONE		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	DE 3100662 A1 (NEUPERT) 26 NOVEMBER 1981 (26/11/81), PAGES 2-4 AND FIGS. 1-2.	1-3, 23 --- 24
X	US 3,857,626 A (ROSENBERGER ET AL) 31 DECEMBER 1974 (31/12/74), SEE COLUMNS 1-3 AND THE SINGLE FIGURE.	1-8, 10-14 AND 19-23
X --- Y	US 2,357,378 A (BENFORD) 5 SEPTEMBER 1944 (05/09/44), SEE COLUMNS 2-5 AND FIGS. 1-2.	1-15 AND 19-23 ----- 16-18 AND 24
Y	EP 0 185 782 A1 (HARDER ET AL) 2 JULY 1986 (02/07/86), SEE PAGES 6-7 AND FIGS. 4-5.	16-18
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "A" document member of the same patent family		
Date of the actual completion of the international search 28 APRIL 1999		Date of mailing of the international search report 20 MAY 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer THONG Q. NGUYEN Telephone No. (703) 308-4814

